Physics 375, Laboratory 2
AC Filters

Overview

The purpose of this experiment is use capacitors and inductors in simple AC circuits, and to use a function generator and rms voltage measurement to investigate the frequency dependence of gain in AC circuits.

Background

Impedance is a quantity used to extend Kirchoff's laws to AC circuits. The impedance of a resistor is just its resistance R. Capacitors and inductors have characteristic impedances of $1/j\omega C$ and $j\omega L$ respectively. Because both capacitors and inductors have frequency-dependent impedances, the behavior of a circuit with these components will also vary with frequency. Remember, in AC theory ω is an angular frequency and is related to the frequency f in Hz by $\omega = 2\pi f$.

A resistor and capacitor can form a voltage divider with a gain that depends on frequency. A low pass filter is a divider that has a gain of 0 dB for low frequencies, and a high pass filter has a gain of 0 dB at high frequencies. The point where low frequency behavior changes to high frequency behavior is called the breakpoint frequency. The breakpoint frequency of an RC circuit is $1/RC$.

An inductor in combination with a capacitor can form a resonant circuit. The resonant frequency of an LC circuit is $\omega_0 = (LC)^{-1/2}$. The quality, Q, of an LC circuit is a measure of the sharpness of the resonance and depends on the resistance R. An RLC circuit has $Q = \omega_0 L/R = (L/R^2 C)^{1/2}$. Practically, Q is measured at resonance by comparing the width of the resonance $\Delta\omega$ to the resonant frequency, so $Q = \omega_0/\Delta\omega$. In this case the width is measured between the frequencies where the power dissipated is half that at resonance. For a sinusoidal signal the half-power frequency is the point where the voltage is $1/\sqrt{2} = 70\%$ of its value at resonance.

1. Low Pass RC Filter

Connect the AC signal generator, DMM to measure AC volts, a resistor and capacitor in a circuit:
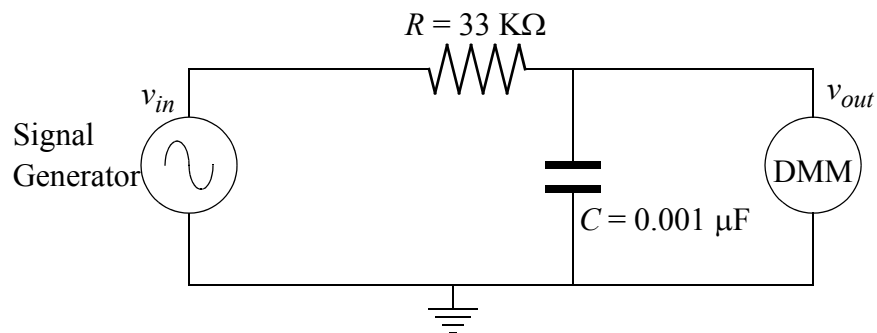

Figure 1: Low Pass RC Circuit

Set the signal generator so that the counter reads 100 Hz and the DMM reads 5.0 V, use the high output of the signal generator. Measure the voltage for each of the following frequencies: 1.0 KHz, 2.0 KHz, 4.0 KHz, 6.0 KHz, 10.0 KHz, 20 KHz and 40 KHz, and place the voltage and the ratio of $A=v_{out}/v_{in}$ in dB in a table. Use the values in the table to make a graph of A vs. $\log f$. What is the slope of the line in dB/octave?

Based on the values of the resistor and capacitor, what is the expected breakpoint frequency? Set the signal generator to give the expected breakpoint frequency. What is the measured voltage drop in dB at the breakpoint frequency?

2. Parallel LC Filter

Build the following circuit using the signal generator, resistor, capacitor and inductor:
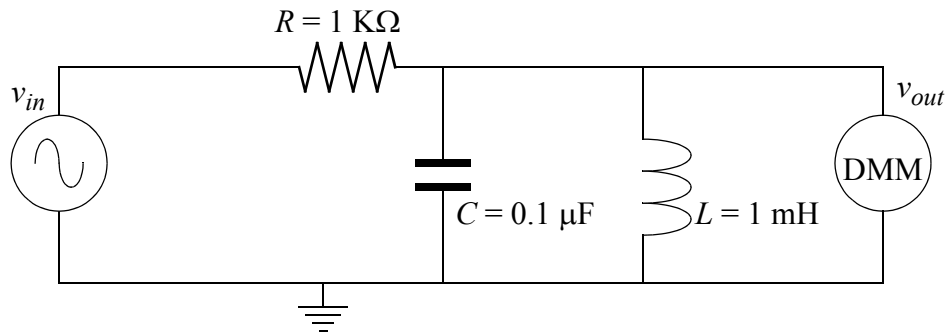

Figure 2: Parallel LC Circuit

Measure the voltage for each of the following frequencies: 2.0 KHz, 5.0 KHz, 10.0 KHz, 15 KHz, 20 KHz, 25 KHz, 30 KHz and 40 KHz, and place the voltage and gain in a table. Use the values in the table to make a graph of A vs. f. Alter the frequency to find the value that gives the maximum gain. Based on the values of the capacitor and inductor, what is the expected resonant frequency and how does it compare to the measured value?

Use the voltage at the measured peak frequency to calculate the value of the voltage at the half-power frequencies. Use the function generator to find the half-power frequencies and the difference between them (Δf). Calculate a value for Q from the measured resonant and half-power frequencies and compare to the theoretical value of Q from the values of R, L and C. Do they agree within measurement error?